Improving Week 3-4 Weather Prediction Through a Global Convection-Allowing Version of the NOAA Unified Coupled Modeling Framework

Briefing to NGGPS
6 November 2019

Team: Ben Cash, Paul Dirmeyer, Jim Kinter, Larry Marx, Chul-Su Shin, Ravi Shukla
Project Overview

• Test potential for improving sub-seasonal to seasonal (S2S) forecasts through enhancing the resolution of the global atmospheric component in UFS to convection-allowing scale.

• Increasing the spatial resolution of global climate models demonstrably enhances S2S prediction skill.

• However, there are limits.
  • Deficiencies in sub-grid scale parameterizations may mask the benefits of increased resolution.
  • Major drivers of S2S weather variability depend on the organization, extent, intensity and frequency of deep convection, especially in the tropics.

• Hypothesis: Poorly resolved cumulus convection can degrade global forecasts at all lead times.

• Hypothesis test: a series of sub-seasonal ensemble re-forecast experiments employing 3 different configurations of a global model:
  1. Global “NWP” resolution (C768 – 13 km)
  2. Global “convection allowing” model (CAM) resolution (C3072 – 3.5 km)
  3. “Nested/stretched grid” resolution to capture tropical convection (suggested by Weber and Mass, 2019)
     • CAM grid (3.5 km) in the tropics
     • NWP grid (13 km) outside the tropics
Project Overview

• Requirements
  • Atmospheric initial conditions at C768 and C3072, e.g., from reanalyses*
  • Oceanic initial conditions at 0.25° *
  • Land surface initial conditions
  • Sea ice initial conditions
  • UFS (FV3-GFS + MOM6 + Sea Ice Model) running at C768/0.25° and C3072/0.25°
  • Post-processing (workflow)
    • All codes and workflows to be made available to UFS community via github

• Evaluation: Differences in weeks 3-4 forecast skill for precip and T$_{2m}$ in the contiguous United States, including the potential for outlooks of extremes
  • Local contributions from explicit representation of cumulus vs. teleconnections

* No data assimilation cycling
Project Overview

• Progress
  • Ported UFS to Stampede2
    • Collaboration with NCAR (many thanks to Rocky Dunlap, Ufuk Turuncoglu, Mariana Vertenstein)
    • Able to run UFS 4-component system with CMEPS Mediator (see next slide) at Cheyenne (NCAR) and Stampede-2 (TACC/XSEDE)
    • MET/METPlus also ported to Stampede-2 (thanks to Julie Prestopnik)
  • Obtained XSEDE computing resources for phase I (“NWP” reforecasts)
    • 516K node-hours (24.7 million core-hours)
  • Developed python-based workflow modules to ingest atmospheric ICs, oceanic ICs from outside sources
    • CFS-A (2011-present) or CFS-R, via chgres, for atmosphere, land surface, ocean, sea ice
    • ERA-5 for atmosphere (land – later)
    • ORA-S5 for ocean (sea ice – later)
  • Developed python-based workflow modules to post-process atmosphere, ocean forecast output
Model Configuration – This Project

- **FV3-GFS**
  - Noah
  - C384 (25 km)
  - C768 (13 km)
  - C3072 (3.5 km)

- **CMEPS mediator**

- **ORA-S5**

- **CICE-5**

- **ERA5**

- **NOCHEM COMPONENT**

- **NO WAVES COMPONENT**

- **CFS-A**

- **CFS-R**
Example: ICs from CFS-A

UFS U wind at 200 hPa
00Z01Jul2012 (CFS-A)
5-day run of UFS CMEPS0.5 initialized by ORA-S5 Temperature and Salinity
(IC: 00Z 01 January 2012)

**CTRL:** Default ICs based on NCEP CFS analyses (*ocean T and S IC: 1°x1° regular lat/lon grid with 40 vertical levels*)

**EXP:** Same as CTRL but ECMWF ORA-S5 T and S IC (0.25°x0.25° regular lat/lon grid with 74 vertical levels)

---

**Surface Boundary Layer Depth (m) at day 5**
(6-hourly mean for 18z-00z at day 5)
Sample Run C384 / 0.25°

UFS U wind at 200 hPa Initial Condition
00Z01Jul2012 (CFS-A)

UFS U wind at 200 hPa Weeks 3-4 Mean
00Z07Jul2012 – 18Z29Jul2012

November 2019 – Jim Kinter
Sample Run C384 / 0.25°

UFS U wind at 200 hPa 01-31 July mean
ICs: 01Jul2012 (CFS-A)

UFS U wind at 200 hPa 01-31 July mean
Verification (CFS-A)
Water Cycle Spinup

C384 / 0.25°
FV3GFS / MOM6-CICE5
01 July 2012 ICs

ERA5 Atmos ICs vs. CFS-R Atmos ICs
CFS-A Ocean and Sea Ice ICs

<table>
<thead>
<tr>
<th>Forecast Period (hrs)</th>
<th>CFS-A ICs</th>
<th>ERA5 ICs</th>
</tr>
</thead>
<tbody>
<tr>
<td>00 – 01</td>
<td>8.07</td>
<td>5.08</td>
</tr>
<tr>
<td>00 – 24</td>
<td>4.04</td>
<td>3.35</td>
</tr>
<tr>
<td>144 – 168</td>
<td>3.32</td>
<td>3.28</td>
</tr>
</tbody>
</table>
C384 / 0.25°
FV3GFS / MOM6-CICE5
01 July 2012 ICs

CFS-A Ocean and Sea Ice ICs

ERA5 Atmos ICs

Precip Rate (mm/d) Hrs 0 - 24

GM = 4.04

Precip Rate (mm/d) Hrs 144 - 168

GM = 3.32

GM = 3.35

GM = 3.28

November 2019 – Jim Kinter
Next Steps

• Configure model for "NWP" resolution (C768/0.25°)
  • Exchange grid, land-sea mask, other fixed fields
  • Initial conditions from ERA-5

• Initialize land surface from external source (see next slide)

• Initialize sea ice from external source (e.g. ORA-S5)

• Configure model for "CAM" resolution (C3072/0.25°)
  • Collaboration with Lucas Harris (GFDL)

• Obtain computing resources for CAM runs
Land-Atmosphere

- Goal: Incorporate in UFS a unified Noah-MP+WRF-Hydro model in fully coupled Earth system model (ESM) with application to global Weather and S2S prediction

- Requirements:
  - Unify terrestrial land and hydrology physics for multiple scales under UFS, prioritizing proper representation of important coupled processes.
  - Ensure scaling consistency between land-hydrology (~1km) and UFS atmosphere grid (global NWP and S2S; ~10km) to properly represent land-hydrology-atmosphere exchanges.
  - Focus on Weather to Subseasonal applications:
    - Land states and fluxes have the greatest impact on prediction at diurnal to subseasonal time scales
    - Improvements in LS (initialization and physics) will improve simulation of land states and fluxes
    - Therefore, more realistic land-hydrology modeling in UFS will improve NWP to S2S prediction, particularly for surface variables such as temperature and precipitation.

- Short-term: Couple the Noah-MP model as a separate component in UFS
- Long-term: Consider unifying Noah-MP, WRF-Hydro and CLM (plant phenology, carbon cycle, soil thermodynamics, land cover tiling, etc.)
Model Configuration – Near-Term

- FV3-GFS
- Atm Chem Aerosols
- NoahMP
- WaveWatch-III
- CMEPS mediator
- MOM-6
- CICE-5
Model Configuration – Long-Term

- FV3-GFS
- Atm Chem Aerosols
- NoahMP/WRF-Hydro/CLM
- WaveWatch-III
- CMEPS mediator
- MOM-6
- CICE-5